QuickBird Panchromatic Imagery: Spatial Resolution Evaluation

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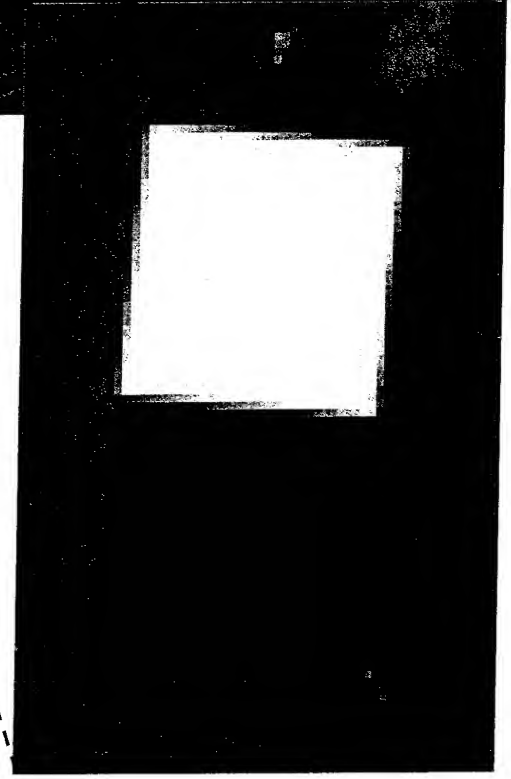
Stennis Space Center, Mississippi

SSC Edge Targets

- In-flight edge response measurements are used to evaluate spatial resolution of commercial remote sensing image products.

- Spatial resolution is characterized with both Full Width at Half Maximum (FWHM) of Point Spread Function (PSF) and Modulation Transfer Function (MTF) at Nyquist spatial frequency.

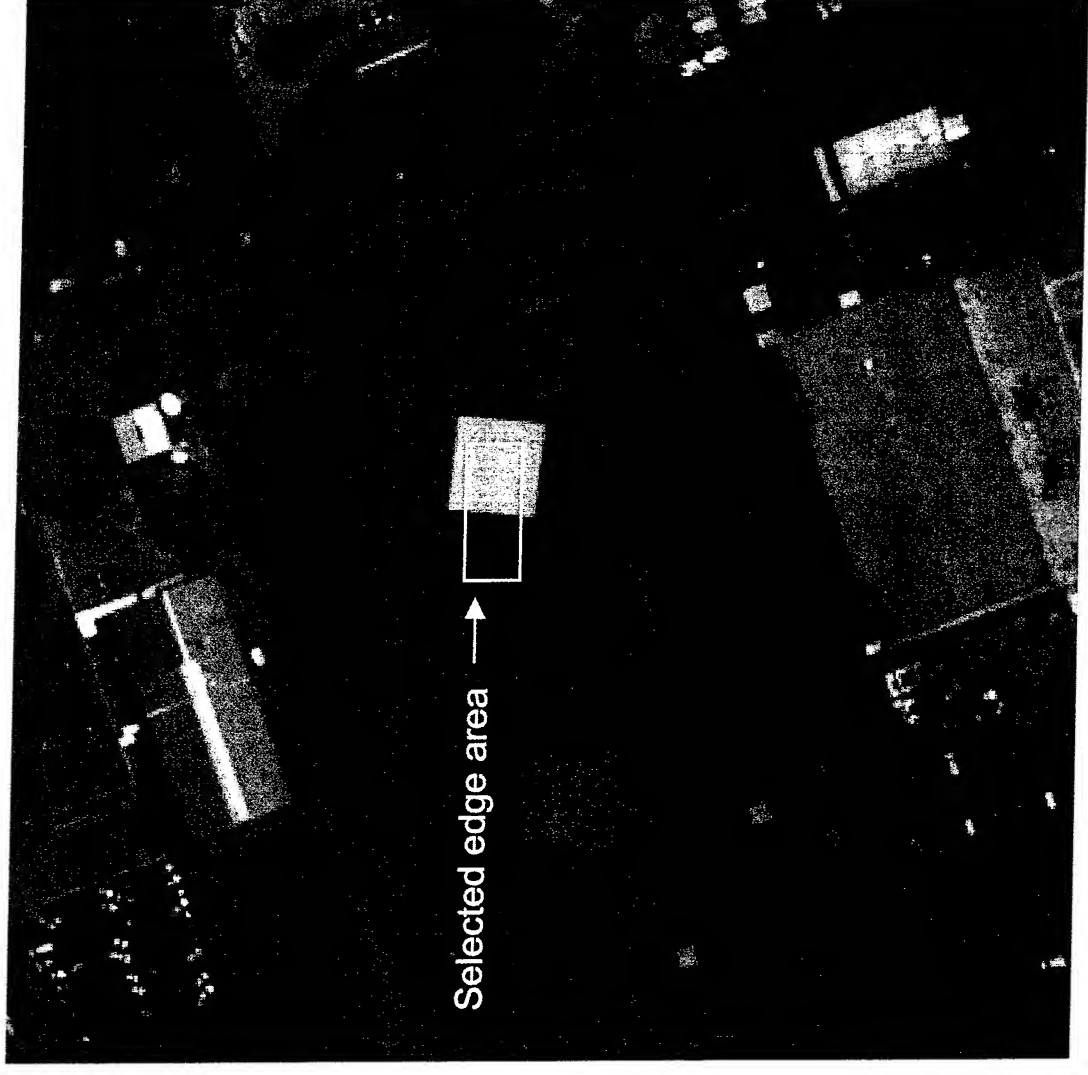*QuickBird panchromatic image of the SSC edge target tarps deployed on November 14, 2002*

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Edge Response Selection

Selected edge area →

- Rectangular area of the edge target image is selected for the edge response analysis.

- Effects of the adjacent surfaces (grass) must be avoided.

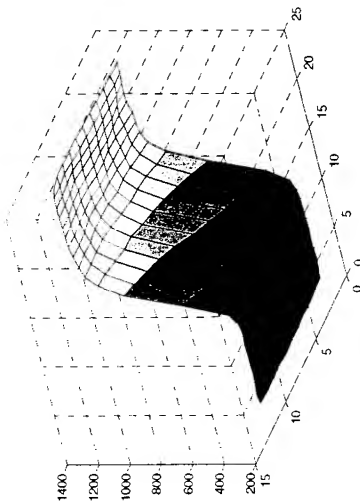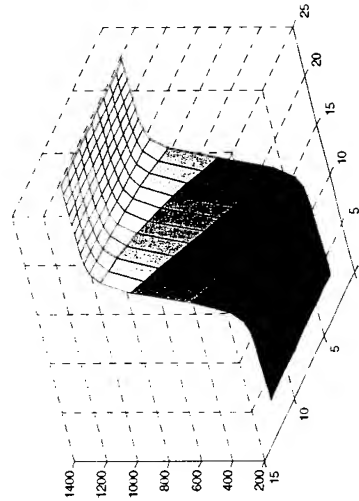- Uniformity of the edge target panels is still the greatest challenge.

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Edge Response Analysis

- Selected edge area includes a set of edge responses, each with an edge position shifted by a fraction of a pixel from an adjacent response.

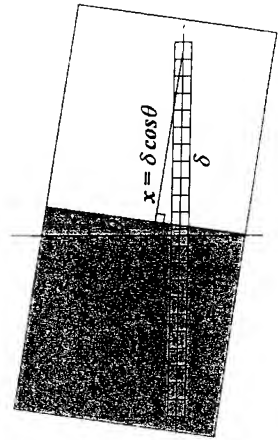- Nonlinear least-square fit of a two-dimensional function that is a linear combination of three sigmoidal functions.

$$e_i(x) = d + \sum_{k=1}^{3} \frac{a_k}{1 + \exp\left[\dfrac{b_1 \Delta i + b_2 - x}{c_k}\right]}$$

- Optimized parameters: $a_1, a_2, a_3, b_1, b_2, c_1, c_2, c_3, d$
- Position and orientation of the edge, described by parameters b_1 and b_2, are found *simultaneously* with the parameters characterizing spatial resolution ($c_1, c_2,$ and c_3)
- Measured edge tilt: $\theta = \tan^{-1}(b_1)$
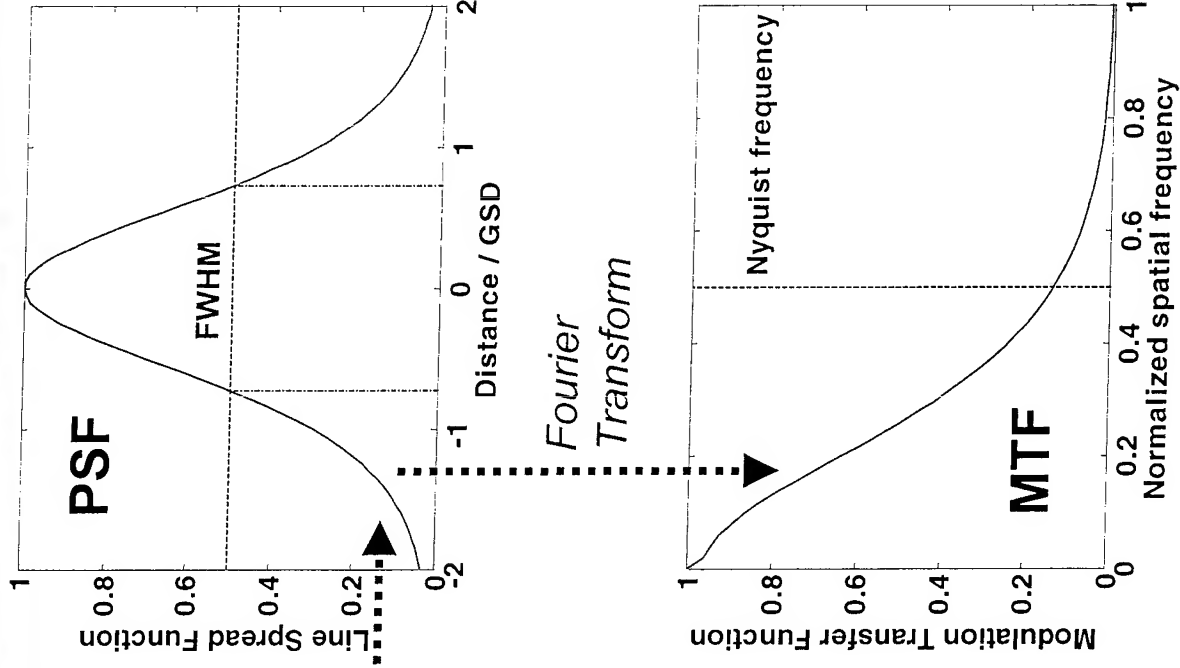- Distance is scaled by cosine of the edge tilt angle:

$$x = \delta \cos\theta$$

$x = \delta\cos\theta$

δ

Actual intensity in the edge area

Best fit with the sigmoidal functions

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PSF and MTF Derivation

- Finding position and orientation of the edge allows for shifting of the edge responses to a single reference location so that all the edge points are aligned.

- Superimposing all the shifted edge responses creates a new edge response with a finer spatial sampling.

- Optimized edge response is generated with arbitrary spatial resolution from the best-fit parameters.

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QuickBird Image Acquisitions

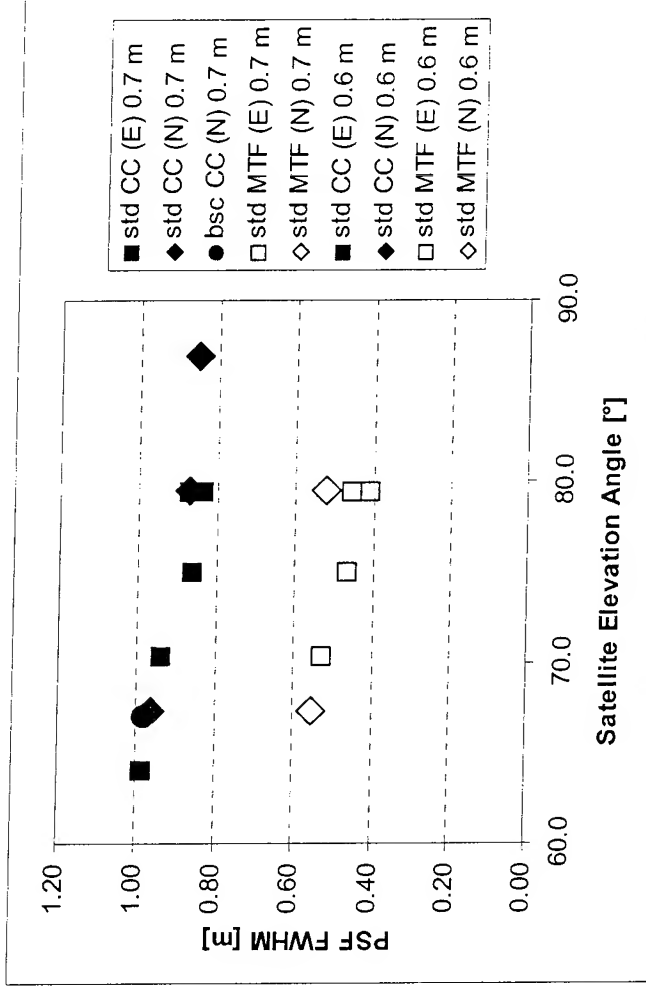| Date	Location	Product GSD (m)	Satellite Elevation Angle (°)	Satellite Azimuth Angle (°)
17-Feb-02	Stennis Space Center, MS	0.7	67.3	10.5
20-Jul-02	Brookings, SD	0.7	64.1	349.8
25-Aug-02	Brookings, SD	0.7	70.4	332.7
7-Sep-02	Brookings, SD	0.7	75.0	191.2
14-Nov-02	Stennis Space Center, MS	0.6	79.5	275.7
2-Apr-03	Stennis Space Center, MS	0.6	86.9	243.4

Standard (and one basic) image products georeferenced using Cubic Convolution (CC) and Modulation Transfer Function (MTF) resampling.

Point Spread Function

Legend:
- std CC (E) 0.7 m
- std CC (N) 0.7 m
- bsc CC (N) 0.7 m
- std MTF (E) 0.7 m
- std MTF (N) 0.7 m
- std CC (E) 0.6 m
- std CC (N) 0.6 m
- std MTF (E) 0.6 m
- std MTF (N) 0.6 m

Y-axis: PSF FWHM [m] (0.00, 0.20, 0.40, 0.60, 0.80, 1.00, 1.20)

X-axis: Satellite Elevation Angle [°] (60.0, 70.0, 80.0, 90.0)

(E) = Easting (horizontal) direction
(N) = Northing (vertical) direction

- FWHM of PSF measures extent of spatial response for single pixel.

- For QuickBird images with CC resampling, PSF FWHM is approximately equal to 1.3-1.4 × GSD.

- Resampling to smaller GSD only slightly improves (reduces) the extent of spatial response.

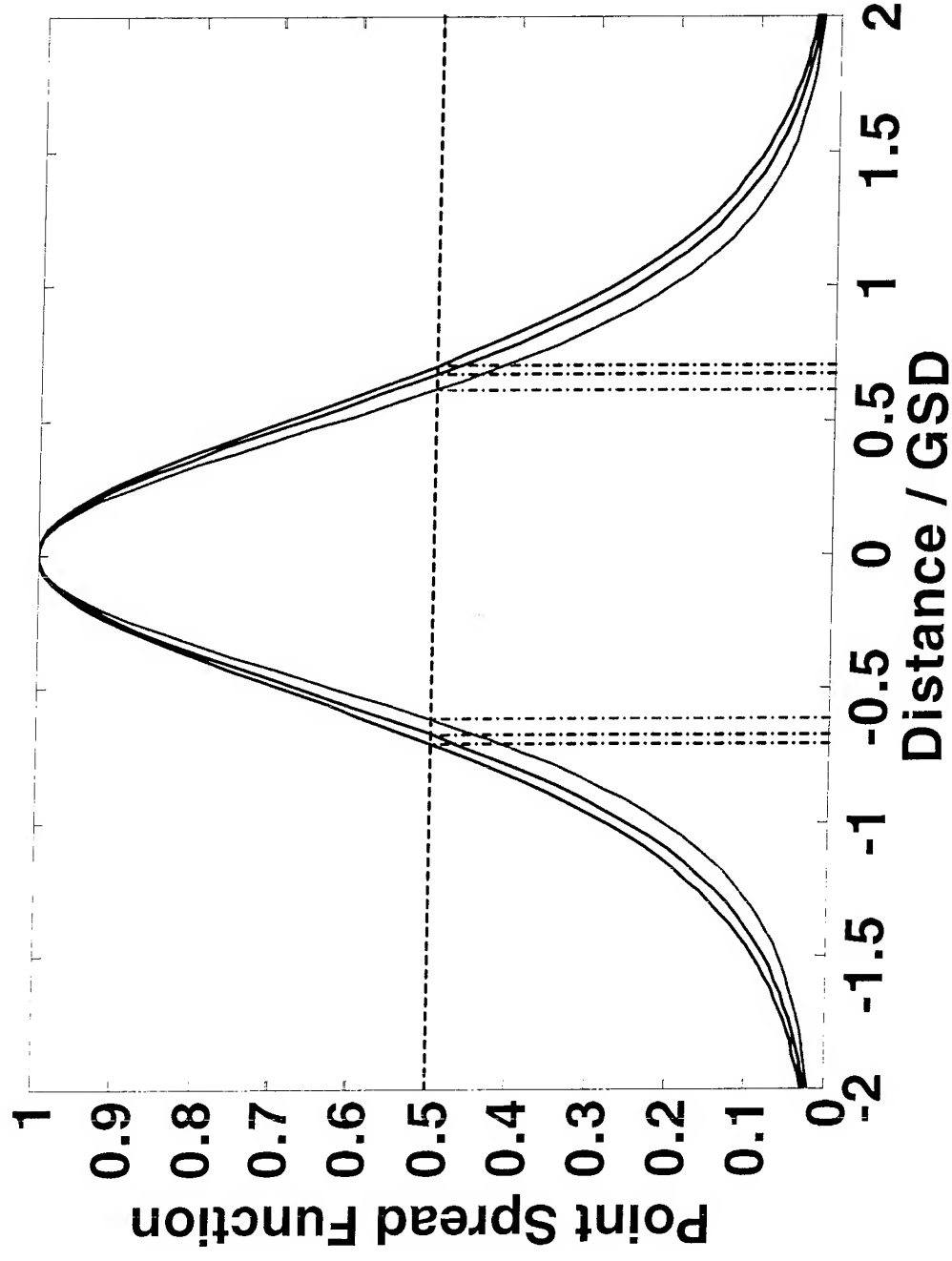- MTF resampling improves spatial resolution by the factor of ~2, but noise and overshoots increase.

PSF Comparison

GSD = 0.7 m

FWHM =
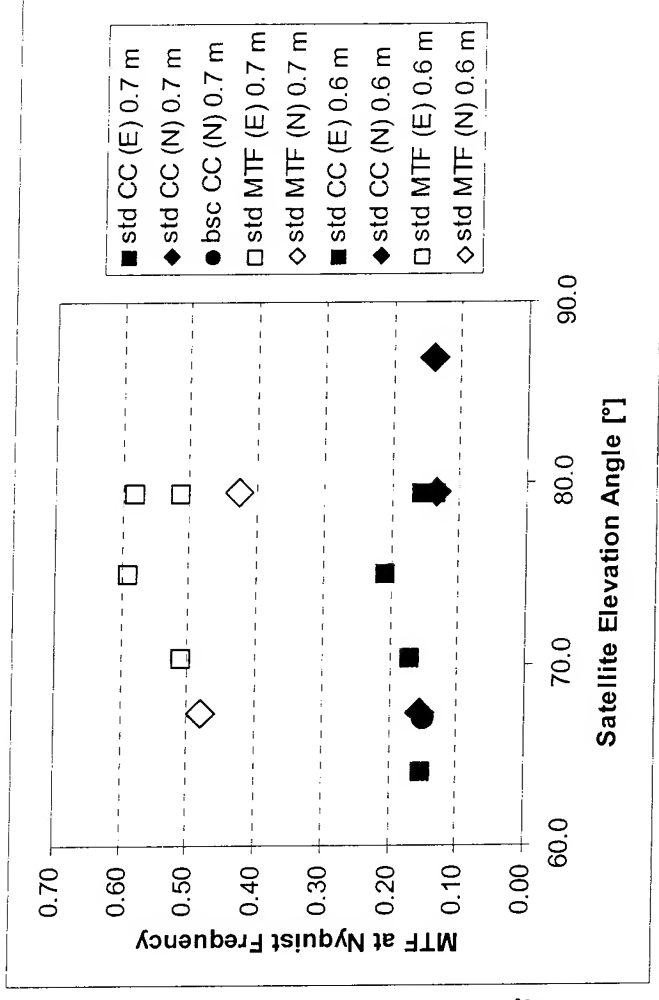
0.98 m   20-Jul-02
0.94 m   25-Aug-02
0.86 m   7-Sep-02

Relatively small
PSF differences

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Modulation Transfer Function

- MTF values at Nyquist spatial frequency exceed NASA Scientific Data Purchase contract requirements for QuickBird image products created with CC as well as with MTF resampling.

- MTF resampling creates images with higher values of MTF at Nyquist frequency (boost).

- Resampling image products to smaller GSD (0.6 m vs. 0.7 m) reduces value of MTF at Nyquist frequency, but NASA requirements are still fulfilled.

Legend:
- std CC (E) 0.7 m
- std CC (N) 0.7 m
- bsc CC (N) 0.7 m
- std MTF (E) 0.7 m
- std MTF (N) 0.7 m
- std CC (E) 0.6 m
- std CC (N) 0.6 m
- std MTF (E) 0.6 m
- std MTF (N) 0.6 m

Y-axis: MTF at Nyquist Frequency (0.00 – 0.70)
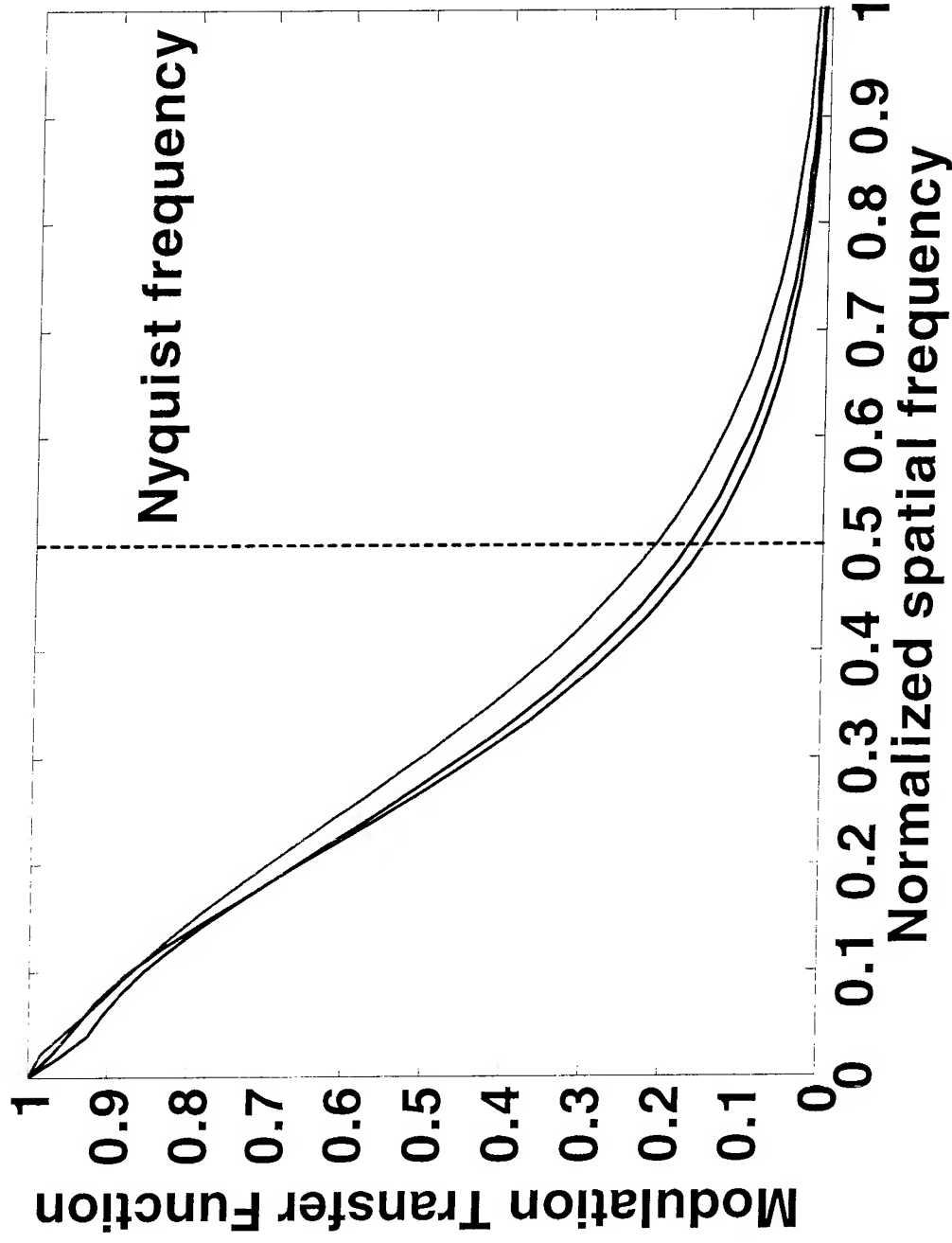X-axis: Satellite Elevation Angle [°] (60.0 – 90.0)

(E) = Easting (horizontal) direction
(N) = Northing (vertical) direction

MTF Comparison

Stennis Space Center

Nyquist
frequency = 0.7 m^{-1}

$\text{MTF}_{\text{Nyquist}}$ =

0.15	20-Jul-02
0.17	25-Aug-02
0.21	7-Sep-02

Larger MTF
differences

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Resampling: MTF vs. CC

Narrower PSF

Higher MTF at Nyquist Frequency

Steeper Edge Response

MTF

CC

DN

Distance / GSD

Point Spread Function

Distance / GSD

Modulation Transfer Function

Nyquist frequency

Normalized spatial frequency

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